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DIGESTIBILITY AND METABOLISM OF FLOUR FROM TWO YAM SPECIES (*D. dumetorum and D. rotundata*) IN SCHOOL AGE CHILDREN

MBOME LAPE I.[1], AGBOR EGBE T.[1] and TRECHE S.[2]

[1]*Centre for Nutrition, P. O. Box 6163, Yaoundé-CAMEROON;* [2]*Centre DGRST-ORSTOM, P. O. Box 181, Brazzaville-CONGO*

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The digestibility and metabolism in school age children of diets from two yam species (*D. dumetorum* and *D. rotundata*) are compared. Ten boys aged 65 to 84 months, with heights and weights close to NCHS reference values, were fed meals deriving half of their protein and almost all of their starch from either of the two yam species. After 6 days of adaptation, food intake, stool and urine were collected for 4 days and analysed. Feeding diet based on *D. dumetorum* resulted in higher apparent protein digestibility, net protein retention and net protein utilisation of 63.5, 46.2 and 29.8, respectively, compared to 56.1, 36.1 and 20.6 for *D. rotundata*-based diet.

KEY WORDS: Yam flour, children, diets, starch, stool, urine, digestibility and metabolism.

INTRODUCTION

The importance of yam (*Dioscorea spp*) in most areas of west and Central African as one of the main starchy food crops has been documented by several authors (Coursey, 1967; Bell and Favier, 1980; Okoli and Onwueme, 1980; Lyonga, 1980). In Cameroon, yam is grown in all the five agro-ecological zones, although more abundantly in the Western Highlands, the Coastal Lowlands and South Cameroon. Apart from providing food for the farm-firm household, yam farming in Cameroon attained a substantial commercial importance, with an estimated 38.4% of total production being sold in the market (Minagri, 1984) and 49% production deficit or unsatisfied demand (Cameroon, 1986).

Of the eight yam species cultivated in Cameroon, *Dioscorea dumetorum,* or the sweet yam as it is popularly known, is the most nutritious. It has a mean protein content of 9.6% (dry weight basis) compared to 8.2 for the water yam (*D. alata*) and 7.0% for *D. rotundata*, the popular white yam (Agbor and Treche, 1983). Its protein is quite balanced in the essential amino acids (with slight deficiency in lysine), and has a chemical score of 94, against 84 for *D. rotundata* protein, when compared to the reference protein (FAO/WHO/UNU, 1985). *D. dumetorum* starch is as digestible as corn starch (Delpeuch and Favier, 1980) as a result of its tiny polygonal or spherical granules (diameter less than 10 microns) with a type A X-ray diffraction structure similar to that of cereals (Robin, 1976).

* Correspondence and checking of proofs : Mbome Lape. Centre for Nutrition, P.O. Box 6163, Yaoundé-CAMEROON.

Agronomically, *D. dumetorum* is high-yielding. Yields of 10 and 40 tons per hectare have been recorded under traditional farming conditions and in agricultural stations, respectively (Lyonga and Ayuk-Takem, 1979; Ngong-Nasah *et al.,* 1980) Unlike the other yams, its staking may be omitted without significantly affecting yield (Waitt, 1963; Lyonga and Ambe, 1985), thus saving labour. Furthermore, its shallow-growing tubers may permit mechanisation of harvest.

Despite these qualities, post-harvest hardening and development of cooking and chewing resistance (Lyonga *et al.,* 1973) of *D. dumetorum* limits its use, storage and commercialisation outside production zones. Generally, tubers are left in the soil and harvested as needed for food and are often boiled before selling in the markets.

To make *D. dumetorum* more useful as food, we have developed a scheme for its processing into instant flour with high nutritive value and long shelf life (Treche *et al.,* 1983; 1984). Rat feeding studies have also been conducted which show that diets based on this *D. dumetorum* instant flour have higher protein efficiency ratio, net protein utilisation and apparent carbohydrate digestibility than similar diets from instant *D. rotundata* flour (Mbome and Treche, 1989).

The aim of this study was to evaluate the biological efficiency of the instant flours from *D. dumetorum* and *D. rotundata* in school age children when fed as *fufu* and porridge, the two common forms in which local flour products are prepared in Cameroon.

MATERIALS AND METHODS

Children

The subjects of the study were 10 boys of ages 64 to 84 months in a mission boarding school at Omvan, 50 kilometers from Yaounde. They were chosen with the consent of their parents and the school authorities. Their heights (106–121 cm) and weights (18.3–22.5 kg) were close to the reference values of the U.S. National Council for Health Service. The children were dewormed with Vermox (mebendazole) 15 days prior to the start of the feeding experiment. An absorption test using xylose (Moshal *et al.,* 1974) indicated that only one child showed signs of malabsorption (excreting less than 16% xylose).

Diets

Yam flours were prepared by thin-slicing of peeled tubers, blanching, drying and milling, as described by Trech *et al.,* (1983). Diets were formulated to derive all their starch from either *D. dumetorum* or *D. rotundata* flour and to provide 90 Kcal and 1.7 g crude protein per kilogram of body weight. This protein level is 6 to 35% lower than that used by Lopez de Romana *et al.* (1980) in a similar study with irish potato, and about 50% higher than the safe level of protein requirement for the growing child (FAO/WHO/UNU, 1985).

Each flour was served as milky porridge, milky-chocolated porridge or *fufu* (prepared by stirring flour in boiling water to a solid gelatinized paste). The children received four meals daily: milky porridge for breakfast; *fufu*, okro sauce and avocado for lunch; milky-chocolated porridge at 16 hOO; *fufu* tomato sauce and mangoes for dinner. The ingredients, preparation and quantity of meals served are given in Table I.

TABLE I
Ingredients and preparation of experimental dishes.

Meal	Dish	Ingredients and preparation (per 100 g fresh weight)	Serving (g fw)
Breakfast (7 h 30)	Milky porridge	Set water containing 5.9 g milk and 9.0 g sugar to boil. Pour 13.5 g yam flour, stir and serve.	300
Lunch (12 h 30)	Avocado	Peeled and cut into slices.	120
	Fufu	Set to boil 67.0 ml water containing 0.08 g salt, pour 33.3 g yam flour, stir out of fire, mold and serve.	375
	Okro sauce (served with *fufu*)	Ingredients are: 9.2 g okro, 5.5 g tomato, 3.0 g onions, 2.4 g water leaves, 0.4 g basilisk, 0.4 g dried *dzom* leaves 0.05 *ndim* grains, 3.8 g fried and peeled groundnut paste, 2.4 g smoked fish, 0.4 g smoked crayfish, 1.2 g salt and 58.0 ml water. 30 kg of sauce are prepared at a time and frozen in batches of 1 kg which are thawed and heated one at each meal.	100
Tea-time (16 h OO)	Milky and chocolated porridge	Set 71.0 ml of water to boil containing 5.2 g milk, 4.8 g cocoa powder and 6.0 g sugar. Pour 12.0 g yam flour, stir out of fire and serve.	300
Dinner (19 h 30)	*Fufu*	Preparation is the same as for lunch.	300
	Tomato sauce (served with *fufu*)	Ingredients are: 20.8 g peeled onions, 30.0 g tomato puree, 6.3 g groundnut oil, 1.2 g salt and 42.0 ml water. Preparation is the same as for okro sauce.	100
	Mango	Peeled and cut into slices.	110

g fw = gram fresh weight.

Experimental Design

The experiment was conducted in two phases of 11 days each during which *D. dumetorum* and *D. rotundata* diets were served successively. The phases were separated by a one week break during which the children received their usual diets. After an adaptation period of 6 days in each phase, food intake was measured and stool and urine were collected for the remaining days. A carmine capsule was fed to each child at the beginning and end of each collection period, and the time between its ingestion and the first appearance of red colour in the stool (intestinal transit time) was noted for each child. All the children were housed in the same dormitory and closely watched day and night to ensure success of the study. Each child was weighed at the beginning and end of each phase, and at 3 day intervals.

At each meal time during the collection periods, representative samples of each dish were made by drawing portions of the same weight as each of the 10 boys was served. Daily collections of the urine of each child was measured and, after adding 0.25% (v/v) of a solution of 10% thymol in isopropanol (for preservation), aliquots of 5% of the volume were drawn and pooled with those of previous days of the same

collection period. Likewise, aliquots of daily faecal collections were taken (after mixing) and pooled. All food, urine and stool samples were frozen immediately after collection until their treatment for analysis.

Chemical Analysis

Analysis of food and faeces samples were done on freeze-dried and ground material. Water content was determined by drying at 105°C to constant weight. Total soluble sugars were determined by the anthron colorimetric method (Loewus, 1952) after extraction in 80% alcohol. Glucose, fructose and sucrose were analysed according to the methods of Johnson *et al.*, (1964), as modified by Cerning-Beroard (1975). The alcohol-insoluble extracts were further refluxed with 40% alcohol for analysis of maltodextrins by the anthron method. Starch content was determined on the resulting residue by the enzymic method of Thivend *et al.*, (1965). Crude fibre content was determined by the formic acid method of Guillemet and Jacquot (1943), and xylose (excreted in urine during the absorption test) by the method of Roe and Rice (1948). Crude protein was analysed by the Kjeldahl method using selenium catalyst mixture (Weininger, 1936) and 6.25 as conversion factor for all samples.

The caloric value of food, stool and urine were determined using a Gallenkamp adiabatic bomb calorimeter. Each ground freeze-dried food and stool sample was made into a tablet of about 1 g using a hand press before determination. Determinations on urine samples were carried out as follows: 0.5 g of crystalline cellulose was added to a preweighed glass crucible containing freeze-dried material from 50 ml of urine; after thorough mixing and recording of the total weight, the whole mixture (less than 1% remained in the crucible) was pressed into a tablet before bomb determination; blank determinations using 0.5 g of crystalline cellulose alone were also made; the caloric value of urine was calculated by subtracting the value for cellulose alone from that for the urine-cellulose mixture.

Biological Evaluation

The following criteria were used to judge the biological efficiency of the diets:

Apparent digestibility of nutrient (%)

$$\frac{\text{nutrient intake} - \text{faecal nutrient}}{\text{nutrient intake}} \times 100$$

Apparent nitrogen retention (%)

$$\frac{\text{nitrogen intake} - \text{faecal nitrogen} - \text{urine nitrogen}}{\text{nitrogen intake} - \text{faecal nitrogen}} \times 100$$

Apparent net protein utilisation (%)

$$\frac{\text{nitrogen intake} - \text{faecal nitrogen} - \text{urine nitrogen}}{\text{nitrogen intake}} \times 100$$

Metabolisable energy (Em)

$$\text{Energy intake} - \text{faecal energy} - \text{urine energy}$$

Em values (in Kcal/100 g sample) from the experiment were compared to those calculated from the equation of Miller and Judd (1984) as follows:

$$Em = [(0.95 - \%F) \times Ec] - (7.5 \times \%N)$$

where %F and %N are respectively the crude fibre and crude protein contents of the diets, and Ec the caloric value per 100 grams.
Energy values were not corrected for hair and skin losses.

Data Analysis

"Students"–t test was used for analysing all data with the exception of those relating to intestinal transit time for which the non-parametric signed rank test was applied.

RESULTS

Composition of Diets

Table II presents the overall composition of the diets. There was no remarkable difference between the two diets, and the level of crude protein was relatively low (2.23 and 2.12% fresh weight or 8.5 and 8.0% dry weight of the *D. dumetorum* and *D. rotundata* diets, respectively). It is to be noted that yam flour provided 48 to 50% of dietary protein, about 53% of energy and more than 99. 6% of starch.

Dietary Intake, Stool and Urine

Analytical data on dietary intake, and on stool and urine excretions during the collection periods are presented in Table III. Differences in the intake of dietary nutrients from the *D. dumetorum* and *D. rotundata*- based diets varied from about

TABLE II
Overall composition of diets.

	Composition of diets (% fresh weight)		% Contribution by yam flour to diets	
	D. dum.	*D. rot.*	*D. dum.*	*D. rot.*
Crude protein	2.23	2.12	49.9	48.5
Fat	2.71	2.64	1.9	0.9
Crude fibre	1.16	1.06	27.9	21.1
Starch	7.04	8.22	99.6	99.7
Digestible carbohydrates (1)	17.08	17.61	62.0	61.4
Crude energy (2)	115.6	114.5	53.4	53.0
Dry weight	26.27	26.44	59.9	60.0

(1) Digestible carbohydrates : starch + maltodextrins + alcohol – soluble sugars
(2) kcal per 100 g fresh weight.

TABLE III
Dietary intake, stool and urine data.

	Dietary intake		Stool		Urine	
	D. d	*D. r*	*D. d*	*D. r*	*D. d*	*D. r*
			(means per 24 hours)			
Total (1)	1620	1657	271.5	226.3	742.5	1075
(2)	425.5	438.0	36.5	38.7	37.5	54.0
Crude protein (g)	36.1	35.3	13.3	15.5	12.3	12.5
Fat (g)	43.7	43.7	5.7	6.5	–	–
Crude fibre (g)	18.4	17.6	7.2	6.6	–	–
Starch (g)	114.1	134.3	0.2	0.7	–	–
Digestible (g) carbohydrates	276.7	287.7	1.3	2.2	–	–
Cr energy (kcal)	1875	1897	179.5	195.7	28.7	26.7

D. d = *D. dumetorum* diet; *D. r* = *D. rotundata* diet.
Values represent averages per child.
(1) in grams fresh weight for diets and stool, and in millilitres for urine.
(2) in grams dry weight.

1.2% for crude energy, through 2.2% for crude protein, to 4.1% for crude fibre. Such variations are however acceptable, given the difficulties encountered in this type of experiment.

Biological Evaluation of Diets

Weight of the children increased from 20.8 ± 1.2 kg (mean ± SD) at the beginning of the study to 21.5 ± 1.37 kg at the end of the 11 days on *D. rotundata* diet. It dropped to 21.3 ± 1.47 kg in the one week interval between the two experimental periods during which the children received their usual diets, and then increased again to 22.3 ± 1.11 kg after 11 days of feeding on the *D. dumetorum* diet.

The digestibility and metabolism of nutrients in the diets are compared in Table IV. Values are derived from data presented in Table III. Food and crude protein intake were significantly different between the two diets ($p < 0.01$), but the differences were small enough not to affect the utilisation of the other nutrients. Intestinal transit time (or time interval between the ingestion and first appearance of carmine marker in stool) was 4 hours longer for the *D. dumetorum* diet than for the *D. rotundata* diet. By the non-parametric rank signed test, this difference is considered significant ($p < 0.05$), in spite of great intra- and inter-individual variability among the subjects. Apparent digestibility of food (total solids), starch, digestible carbohydrates and crude fibre did not vary with the diets, except for that of fat which was slightly higher for the *D. dumetorum* diet than for the *D. rotundata* diet ($p < 0.01$).

Differences in the caloric values of diets ($p < 0.01$) reflected on the metabolisable energy (experimental or calculated), but did not show any significant effect on the energy ratios Ed/Ec, Em/Ed and Em/Ec. Apparent protein digestibility, nitrogen retention and net protein utilisation were significantly lower for the *D. rotundata* diet by about 12, 19 and 27%, respectively.

TABLE IV
Biological evaluation of diets.

		D. dum. diet	*D. rot.* diet	*level* sign.
Overall daily intake (means/24 hrs)				
Fresh weight (g)	(1)	1620	1657	$p < 0.01$
Crude protein (g)	(1)	36.1	35.3	$p < 0.01$
	(2)	1.75	1.69	$p < 0.01$
Crude energy (kcal)	(1)	1875	1897	NS
	(2)	90.2	91.3	NS
Intestinal transit time (hr)		23.6	19.3	$p < 0.05$
Apparent digestibility				
Dry matter		91.4	91.1	NS
Digestible carbohydrates	(3)	99.5	99.3	NS
Crude fibre		61.0	62.4	NS
Fat		86.8	85.0	$p < 0.01$
Energy utilisation				
Crude energy (kcal/100 g FW)		115.7	114.5	$p < 0.01$
Met. energy (kcal/100 g FW)	(4)	102.9	101.1	$p < 0.01$
	(5)	107.9	100.1	$p < 0.01$
Ed/Ec		90.4	89.7	NS
Em/Ed		98.3	98.4	NS
Em/Ec		88.9	88.3	NS
Nitrogen Utilisation				
Apparent digestibility (%)		63.5	56.1	$p < 0.01$
App. nitrogen retention (%)		45.9	37.0	$p < 0.001$
App. net prot. utilisation (%)		29.4	21.4	$p < 0.01$

Ec = crude energy;
Ed = digestible energy;
Em = metabolisable energy.
(1) per child
(2) per kg body weight
(3) starch + alcohol – soluble sugars + maltodextrins
(4) determined values
(5) Values derived from the equation of Miller and Judd (1984)

DISCUSSION AND CONCLUSION

The nutritional differences between the flours is reflected mainly by higher apparent protein digestibility and nitrogen retention values for the *D. dumetorum* diet. The apparent digestibility of carbohydrate was similar for both diets despite a difference in the intestinal transit time. High values for apparent digestibility of crude fibre (cellulose and lignin) can be explained by the fact that the fibre-like material formed from starch during cooking, and which resist amylolytic enzyme hydrolysis *in vitro* (Varo *et al.*, 1984; Reistad and Hagen, 1986), are digested in the colon by bacterial enzymes, and thus absent in the stool (Englyst and MacFarlane, 1986).

In the absence of any difference in apparent digestibility of starch or carbohydrates between the two diets, the lower nitrogen retention for the *D. rotundata* diet is most likely caused by its lower protein digestibility, which itself

could be inherent due to a shorter intestinal transit time or to other influences of dietary fibre.

In conclusion, it is the lower protein digestibility, nitrogen retention and net protein utilisation for the *D. rotundata* diet that decrease its value as food source for school-age children compared to the *D. dumetorum* diet. Besides, there are indications from the results that the *D. dumetorum* diet promotes higher growth in the children than the *D. rotundata* diet, despite the shortness of the experiment. The high nutritive value of *D. dumetorum* was also noticed in a feeding assay on 9 to 60 months old children aimed at comparing the effects on growth of a mixture of *D. dumetorum* flour/soybean flour (9:1 v/v) and the CSM (corn, soybean, milk) flour supplied by the World Food Program (Gwangwa'a *et al.*, 1986).

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